

SINGLE AND DOUBLE PION PRODUCTION IN NP COLLISIONS AT 1.25 GEV WITH HADES.

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Abstract

The preliminary results on charged pion production in np collisions at an incident beam energy of 1.25 GeV measured with HADES are presented. The np reactions were isolated in dp collisions at 1.25 GeV/u using the Forward Wall hodoscope, which allowed to register spectator protons. The results for $np \rightarrow pp\pi^-$, $np \rightarrow np\pi^+\pi^-$ and $np \rightarrow d\pi^+\pi^-$ channels are compared with OPE calculations. A reasonable agreement between experimental results and the predictions of the OPE+OBE model is observed.

1 Introduction

Pion production in nucleon-nucleon collisions has been the subject of considerable interest in nuclear and particle physics for many years. A number of experiments have been performed, spanning the energy region from threshold to many GeV's[1, 2]. The bulk of the experimental data has come from pp collision. The pn interaction data in the low and medium energy regions are scarce despite of their importance not only for understanding the NN interactions but also for the interpretation of medium-energy heavy-ion interactions. The np interactions are studied by using deuteron-proton (dp) collisions with the deuteron either as the projectile or as the target. The main reason for this situation is due to the difficulty to create pure monoenergetic neutron beams.

One of the questions which is not answered at the present time is the contribution of isoscalar (I=0) partial waves to the inelastic np collision. The neutron-proton scattering amplitude contains both isoscalar (I=0) and isovector (I=1) parts and, while the isovector part is rather well known, even the order of magnitude of the total isoscalar cross section is badly determined. Usually, this cross-section is extracted from the difference of the total cross-sections of the pion production reactions: $np \rightarrow pp\pi^-$ and $pp \rightarrow pp\pi^0$.

A study of the double pion production in the NN collisions is one way to obtain information about nucleon-nucleon, pion-nucleon, pion-pion interactions and for the investigation of resonances properties. The comparison of the double-pion production from np and pp interaction can bring new constraints on the recently reported e^+e^- excess in the np reaction [3]. Also the study of single and double pion production in np collisions at different energies is important for the determination of both the energy dependence of the total np cross section and the contribution of inelastic channels to np interactions. This paper presents preliminary results for the $np \rightarrow pp\pi^-$, $np \rightarrow np\pi^+\pi^-$ and $np \rightarrow d\pi^+\pi^-$ channels at 1.25 GeV.

2 High Acceptance Di-Electron Spectrometer

The High Acceptance Di-Electron Spectrometer(HADES) is an unique apparatus installed at the heavy-ion synchrotron SIS18 at GSI Darmstadt [4]. It is designed for high-resolution and high-acceptance dielectron spectroscopy in hadron-hadron, hadron-nucleus and nucleus-nucleus reactions at beam energies in the range from 1A GeV to 2A GeV. The major part of the HADES physics program focuses on in-medium properties of the light vector mesons, ρ , ω and ϕ .

The HADES spectrometer consists of 6 identical sectors covering the full azimuthal angle and polar angles from 18° to 85° relative to beam direction. Each sector of the spectrometer contains a Ring Imaging Cherenkov Detector (RICH) operating in a magnetic field,

inner Multi Wire Drift Chambers (MDCs) in front of magnetic field, outer MDCs behind the magnetic field, Time Of Flight (TOF and TOFino) detectors and a electromagnetic cascade detector (Pre-Shower). A detailed description of the HADES spectrometer can be found in [4]. Momentum measurement for charged particles is achieved by tracking the particles in front of and behind a toroidal field generated by six superconducting coils arranged around the beam axis. A hadron-blind Ring Imaging Cherenkov detector (RICH) placed around the target region is used for electron identification, together with TOF/TOFINO and an electromagnetic pre-shower detector (Pre-Shower). Particle identification is also provided using the correlations between time-of-flight and momentum of charged pions, protons and deuterons. Forward Wall (FW) scintillator hodoscope covering the polar angle between 1° and 7° was installed lately 2007 for tagging the spectator proton in dp reactions. With technical design features, HADES can obtain data with high quality and statistical significance.

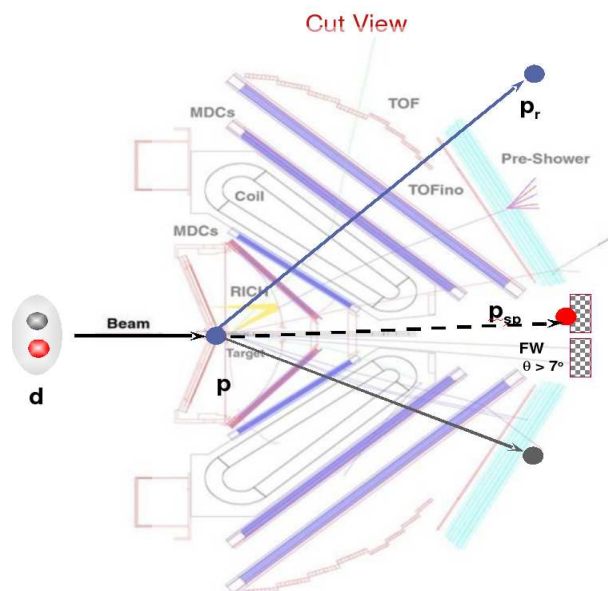


Figure 1: Cut through two sectors of the HADES spectrometer. The magnet coils are projected onto the cut plane to visualize the toroidal magnetic field. A schematic view of the quasi-free $n + p$ reaction is shown.

3 dp experiment

A deuteron beam of 10^7 particles/s with kinetic energy of 1.25 AGeV was incident on a liquid hydrogen cell with a length of 5 cm, corresponding to a interaction length of $\rho d = 0.35 \text{ g/cm}^2$. Quasi-free $n - p$ reactions were selected at the trigger level by detection of fast spectator protons from the deuterium break-up in the FW. The detection of the spectator protons by the FW allowed to suppress the contribution of quasi-free $p - p$ reactions [5]. The FW is an array which consists of nearly 300 scintillating cells with each 2.54 cm thickness. During the dp experiment it was located 7 m downstream the target. The estimated time resolution of the FW is about 500 ps; thus the estimated momentum resolution of the detected particles (protons) is $\sim 11\%$.

4 Results

Fig. 2 exhibits the preliminary missing mass and invariant mass spectra for the $np \rightarrow pp\pi^-$ channel. Both spectra are not efficiency corrected. The vertical line in Fig. 2.a) at $0.03 \text{ GeV}^2/c^4$ shows the criterion on the M_{miss}^2 which was applied to remove events with an additional π^0 production. The experimental M_{inv} distribution is shown in Fig.1.b). Two possible proton combinations were taken into account. The maximum of the distribution correspond to the $\Delta(1232)$ resonance

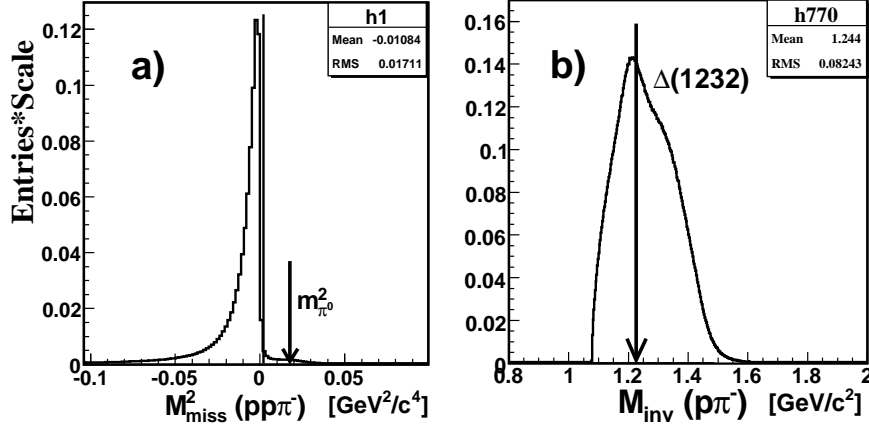


Figure 2: Preliminary results for $np \rightarrow pp\pi^-$ channel. a) - the $pp\pi^-$ missing mass spectrum and b) the $p\pi^-$ invariant mass spectrum. The dashed arrow in a) and the solid arrow in b) correspond to the squared mass of π^0 and the mass of $\Delta(1232)$ resonance, respectively.

Figs. 3. and 4. exhibit preliminary spectra of M_{miss}^2 and M_{inv} for the $np \rightarrow d\pi^+\pi^-$ and $np \rightarrow np\pi^+\pi^-$ channels, respectively. The spectra are not efficiency corrected. Distributions of M_{miss}^2 in Fig. 3.a) and Fig. 4.a) show that channels are separated correctly. Fig. 3.b) and 3.c) correspond to the M_{inv} spectra of $\pi^+\pi^-$ and $d\pi$. Fig. 4.b), 4.c), 4.d), 4.e), 4.f) correspond to the M_{inv} spectra of $\pi^+\pi^-$, $p\pi^+$, $p\pi^-$, $n\pi^+$, $n\pi^-$, respectively. M_{inv} spectra of $p\pi^+$ in Fig. 4.c) show that the np reaction should follow via $np \rightarrow \Delta^{++}n\pi^- \rightarrow np\pi^+\pi^-$.

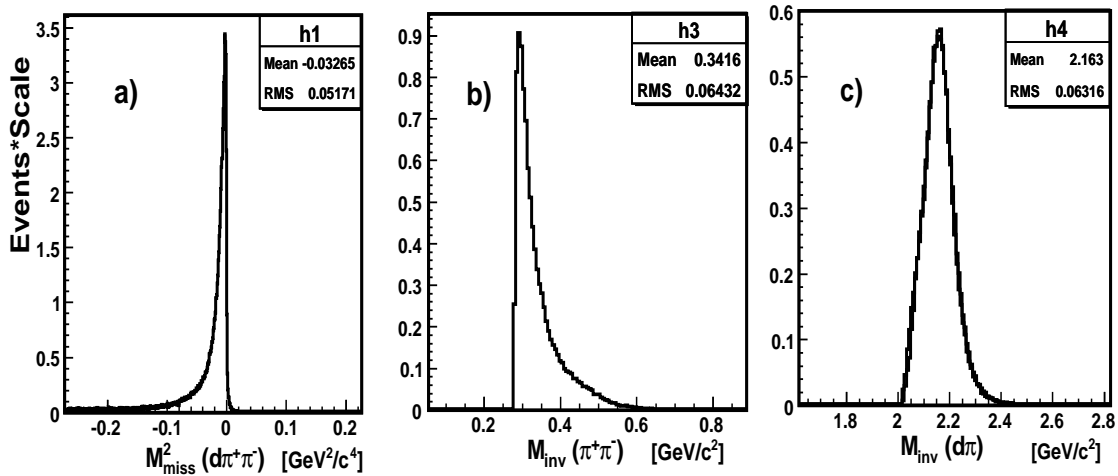


Figure 3: Preliminary results for $np \rightarrow d\pi^+\pi^-$ channel. a) - the $d\pi^+\pi^-$ missing mass spectra, b) - the $\pi^+\pi^-$ invariant mass spectra and c) - $d\pi$ invariant mass spectra.

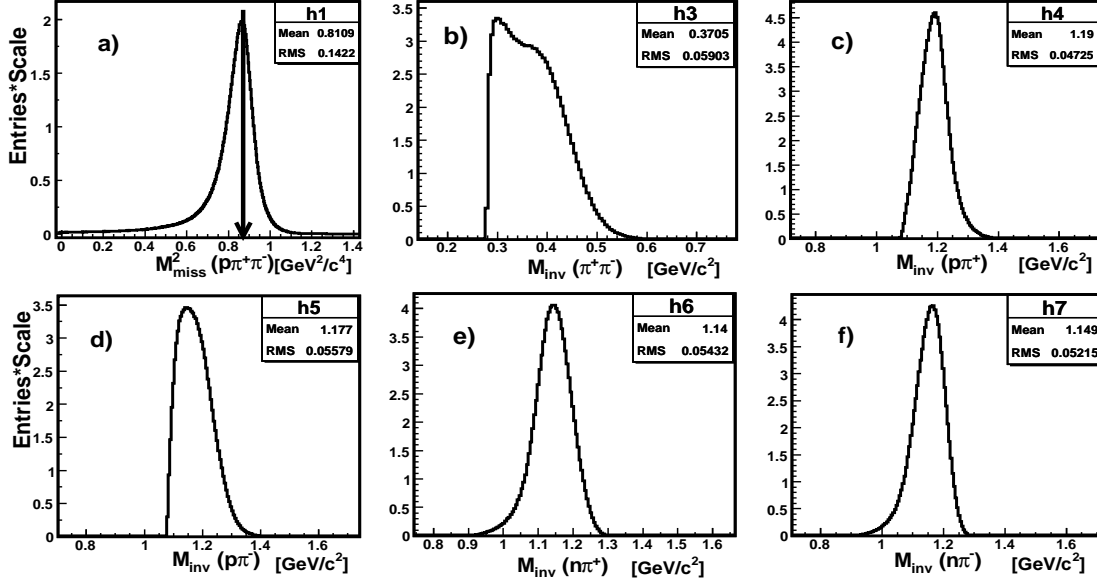


Figure 4: Preliminary results for $np \rightarrow np\pi^+\pi^-$ channel. a) the $p\pi^+\pi^-$ - missing mass spectra, b) the $\pi^+\pi^-$ - invariant mass spectra, c) the $p\pi^+$ - invariant mass spectra, d) the $p\pi^-$ - invariant mass spectra, e) the $n\pi^+$ - invariant mass spectra, f) the $n\pi^-$ - invariant mass spectra. The solid arrow in a) corresponds to the squared neutron mass.

5 Prediction of the Pluto and OPE+OBE models

The predictions of Pluto event generator [6] for the $np \rightarrow pp\pi^-$ and $np \rightarrow d\pi^+\pi^-$ channels are presented in Fig. 5. The spectra show events which belong to the geometric acceptance of HADES. The excitation of $\Delta(1232)$ resonance only was included for the $np \rightarrow pp\pi^-$ process. The phase space was generated for the $np \rightarrow d\pi^+\pi^-$ channel. The behavior of M_{inv} spectra is qualitatively reproduced by Pluto event generator for both channels. However the $\Delta(1232)$ resonance is not so clearly visible in the not corrected by the efficiency experimental distribution (see Fig. 2.b)).

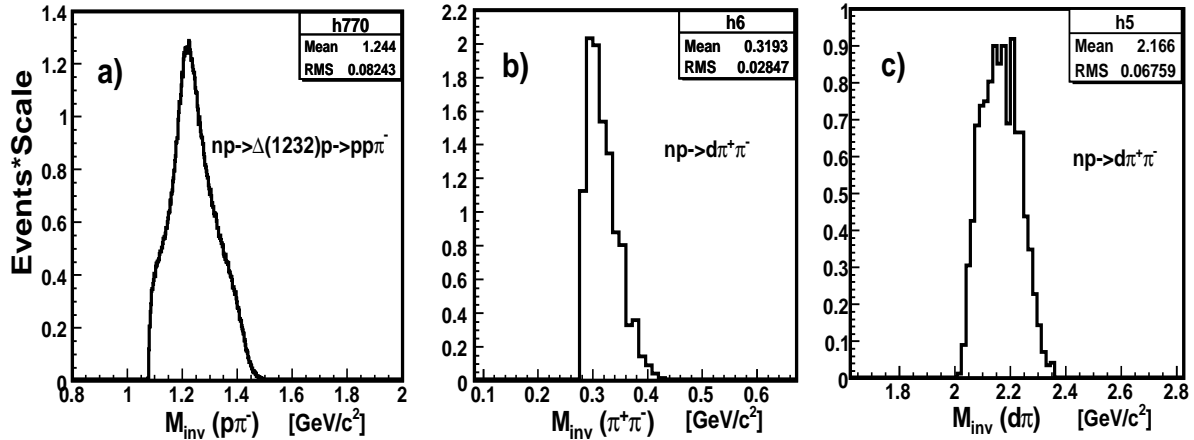


Figure 5: Prediction of Pluto for the $np \rightarrow pp\pi^-$ and $np \rightarrow d\pi^+\pi^-$ channels. Explanations are given in the text.

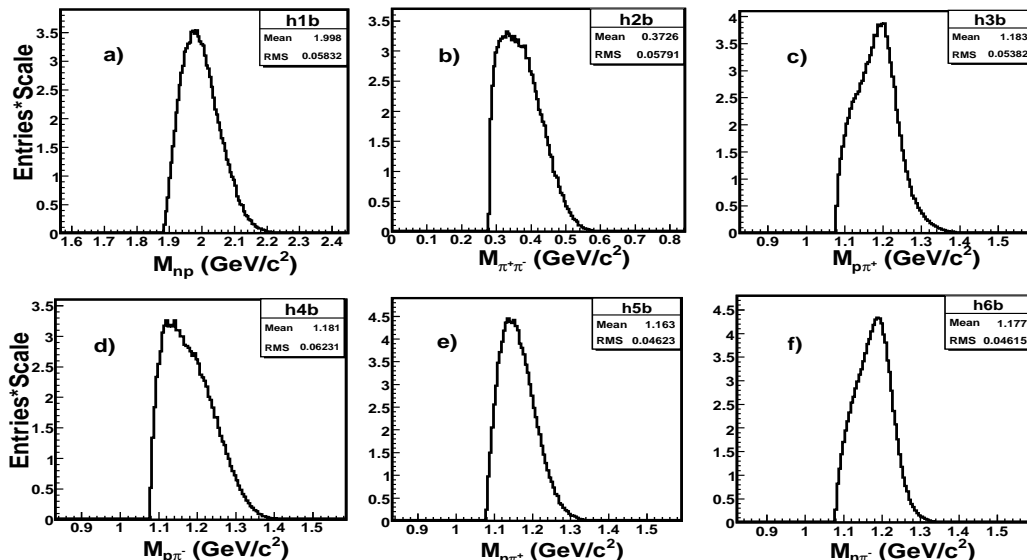


Figure 6: Predictions of OPE+OBE model calculations for $np \rightarrow np\pi^+\pi^-$ channel.

Fig. 6 exhibits the prediction of OPE+OBE (one π -exchange and one barion-exchange) model [7] calculations for the $np \rightarrow np\pi^+\pi^-$ channel. This model include also the interference of the main diagrams of reggeized one π -exchange model (OPER) for $np \rightarrow np\pi^+\pi^-$ reaction at the energies 1-5 GeV [7]. The behavior of M_{inv} spectra (see Fig. 4) is qualitatively reproduced by predictions of the OPE+OBE model. However the experimental data require the correction on the efficiency.

6 Conclusion

The preliminary results on charged pion production in np collisions at 1.25 GeV obtained with HADES are presented. A reasonable agreement of preliminary experimental results and predictions of the Pluto event generator and OPE+OBE model is observed. More detailed information will be obtained through a comparison the efficiency corrected experimental spectra and the simulation results.

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